SEA SALT AEROSOL PRODUCTION:
PARAMETERIZATION AND UNCERTAINTY

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Wednesday, December 15, 2004, 2:40 pm

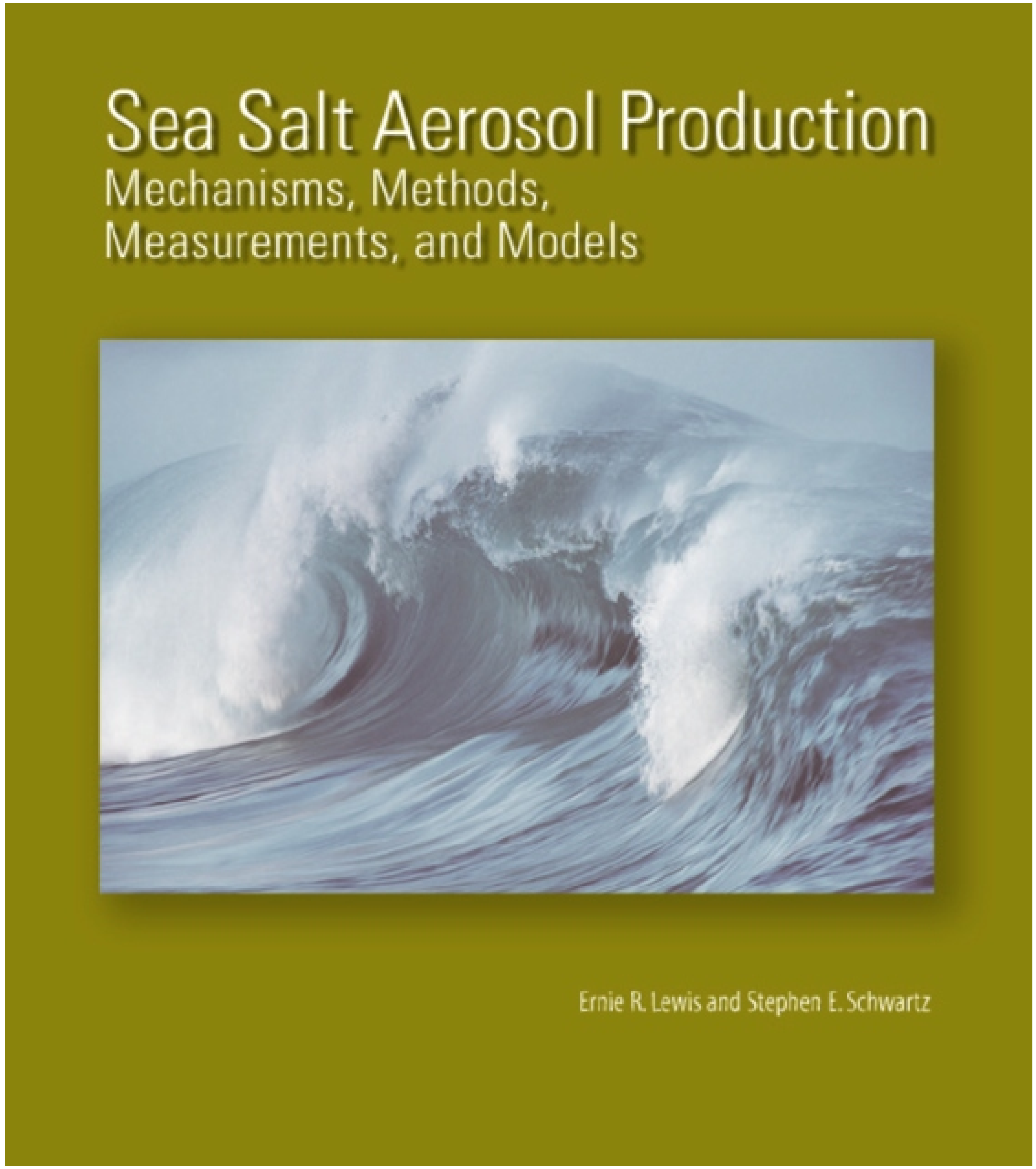
American Geophysical Union
2004 Fall Meeting
San Francisco

IMPORTANCE of SEA SALT AEROSOL (SSA)

- Dominant aerosol species over the oceans
- One of the dominant aerosol species globally

- Light-scattering
  - Earth's radiation balance, global albedo
  - Remote sensing, visibility
- Properties of marine clouds
  - Anthropogenic radiative forcing – Twomey effect
  - Marine hydrology
- Atmospheric chemistry
  - Reactions within SSA particles
  - Nucleation suppression
- Air-sea exchange of latent heat, momentum, moisture

*Accurate parameterization of **size-dependent** SSA concentration and production flux **(including uncertainties)** is necessary.*



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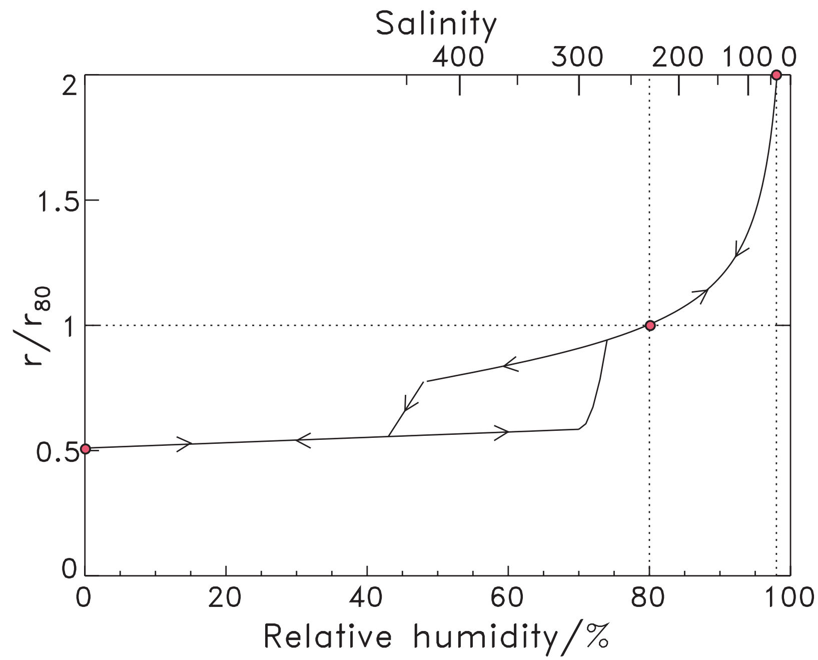
SEA SALT AEROSOL PARTICLES AT 80% RH



r_{80} defined as radius of SSA particle in equilibrium at 80% RH

- r_{80} physically *relevant* (80% RH typical of marine boundary layer)
- r_{80} *unambiguous* (80% RH above hysteresis range)
- r_{80} *independent* of local meteorological conditions (RH)
- $r_{80} \approx 2r_{\mathrm{dry}}$, $r_{80} \approx (1/2)r_{\mathrm{form}}$

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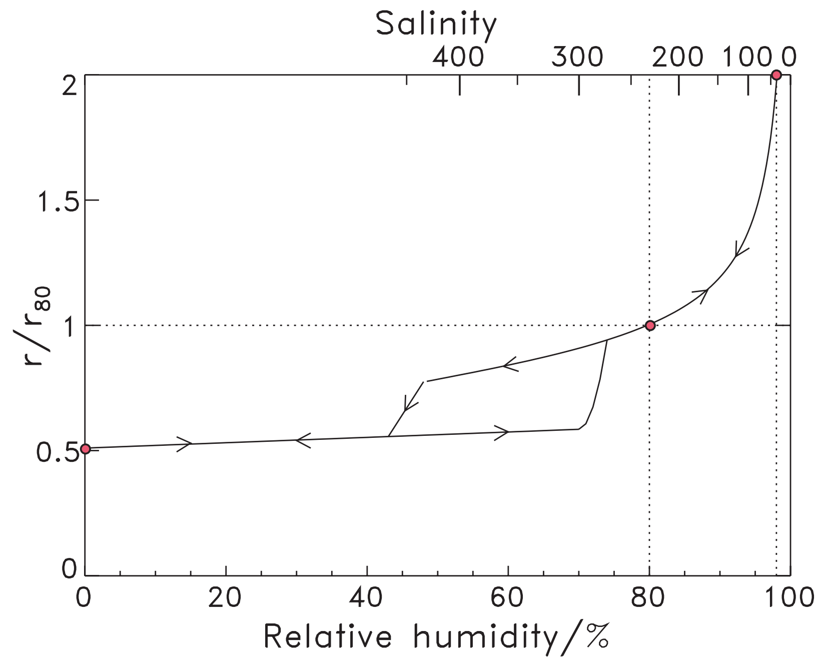

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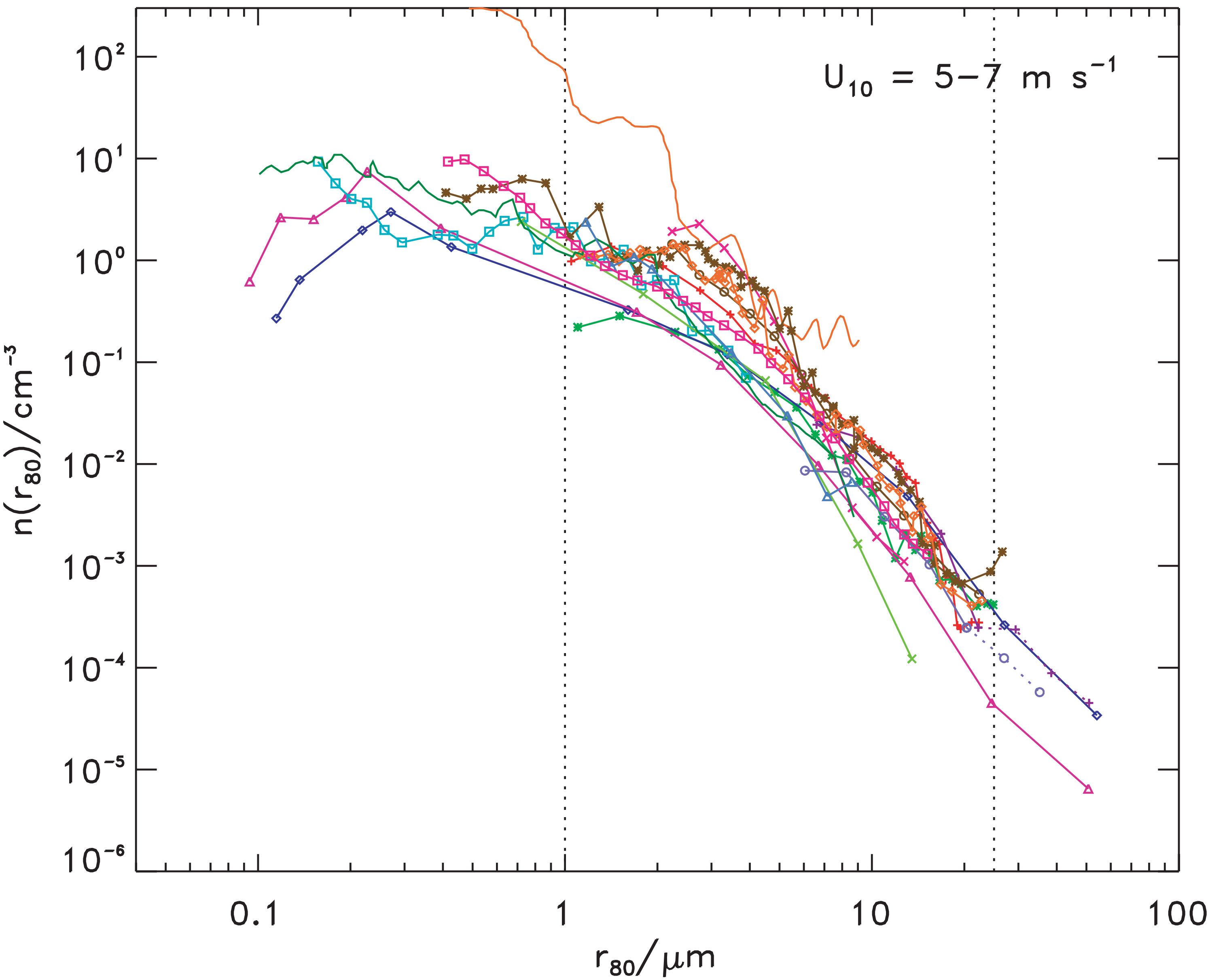
- r_{80} *independent* of local meteorological conditions (RH)
- $r_{80} \approx 2r_{\mathrm{dry}}$, $r_{80} \approx (1/2)r_{\mathrm{form}}$
- "Size" insufficient: $d_{\mathrm{form}} = 2\{r_{\mathrm{form}}\} \approx 2\{2[r_{80}]\} \approx 2\{[2(2r_{\mathrm{dry}})]\}$

SIZE DISTRIBUTION OF SSA NUMBER CONCENTRATION



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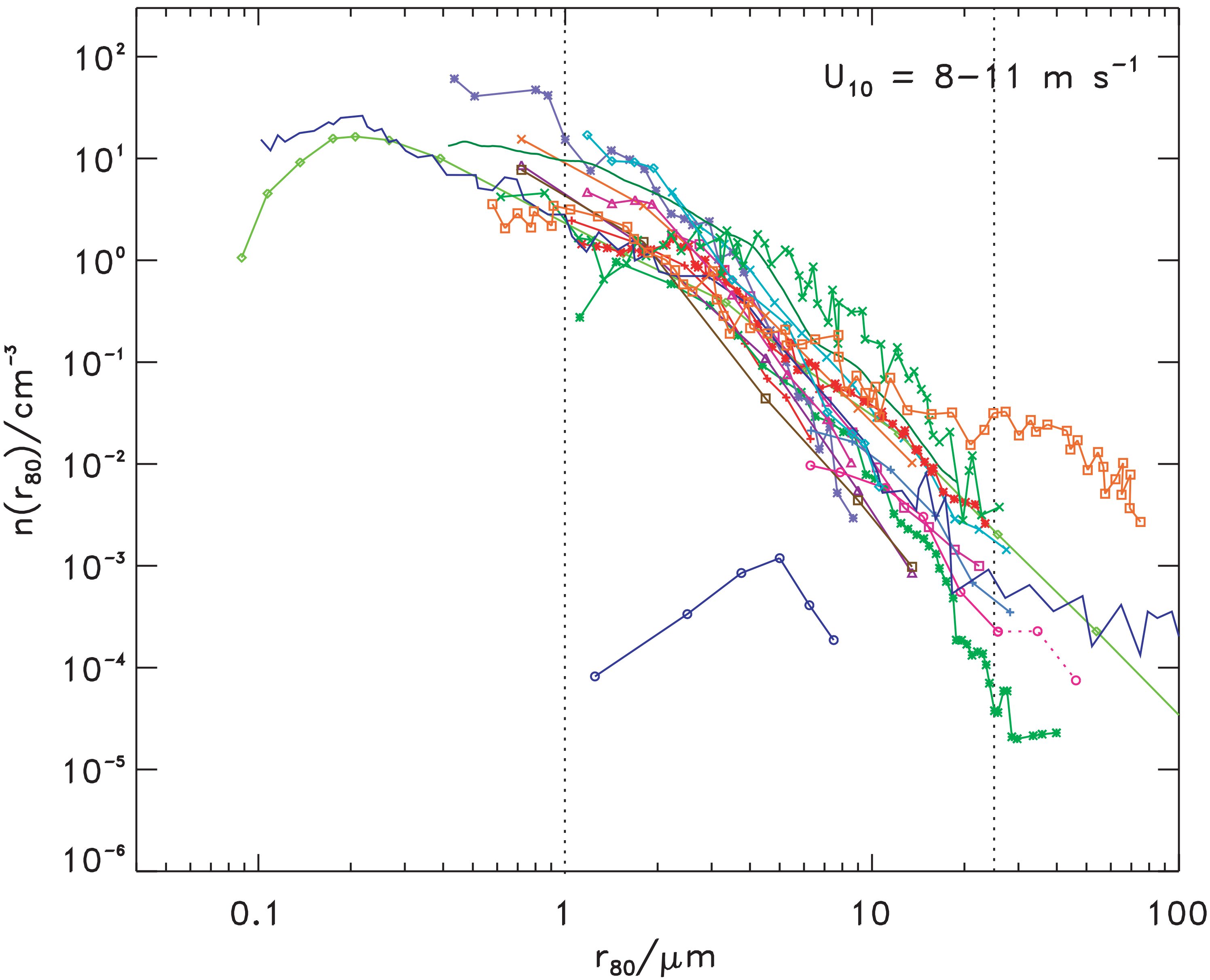

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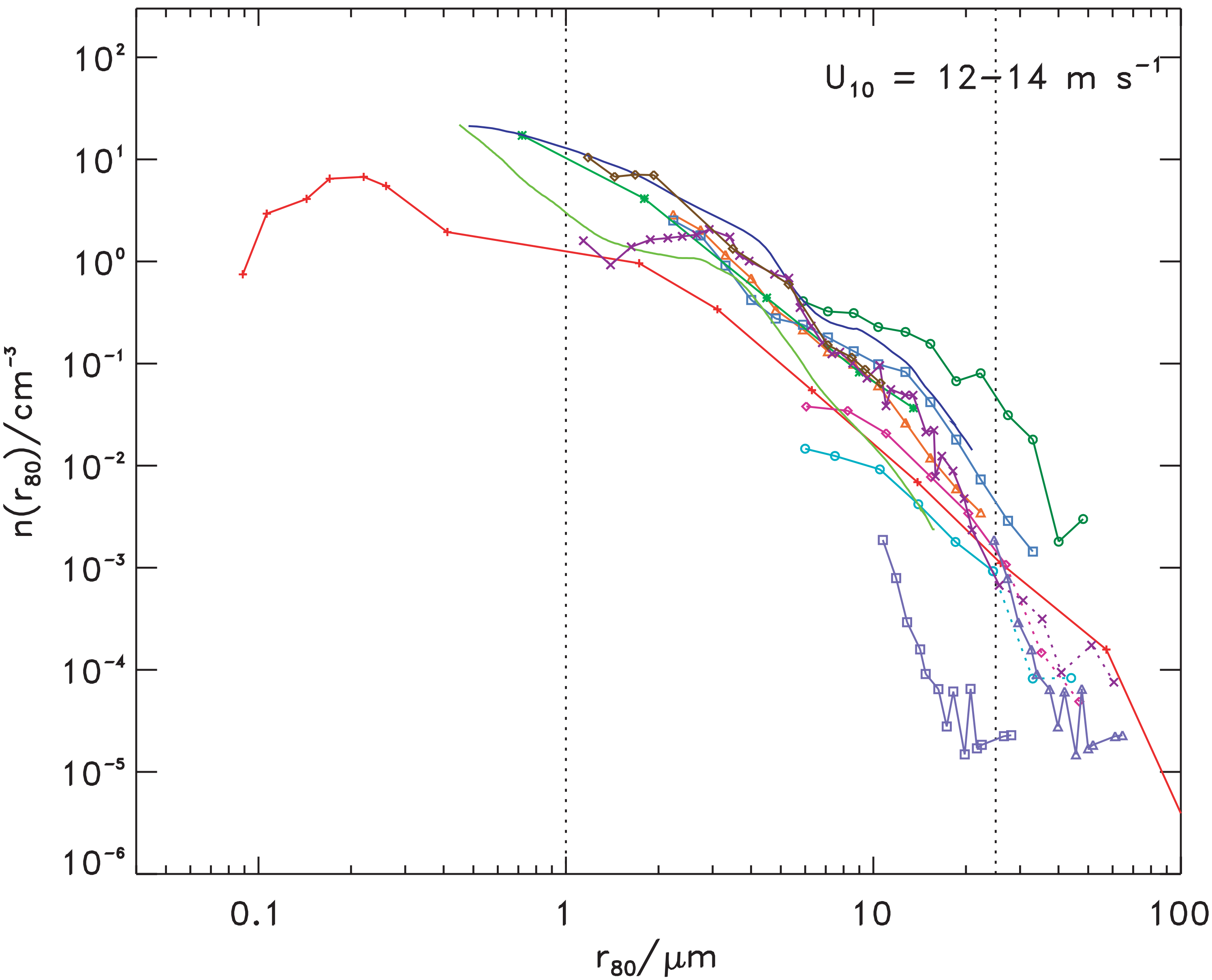

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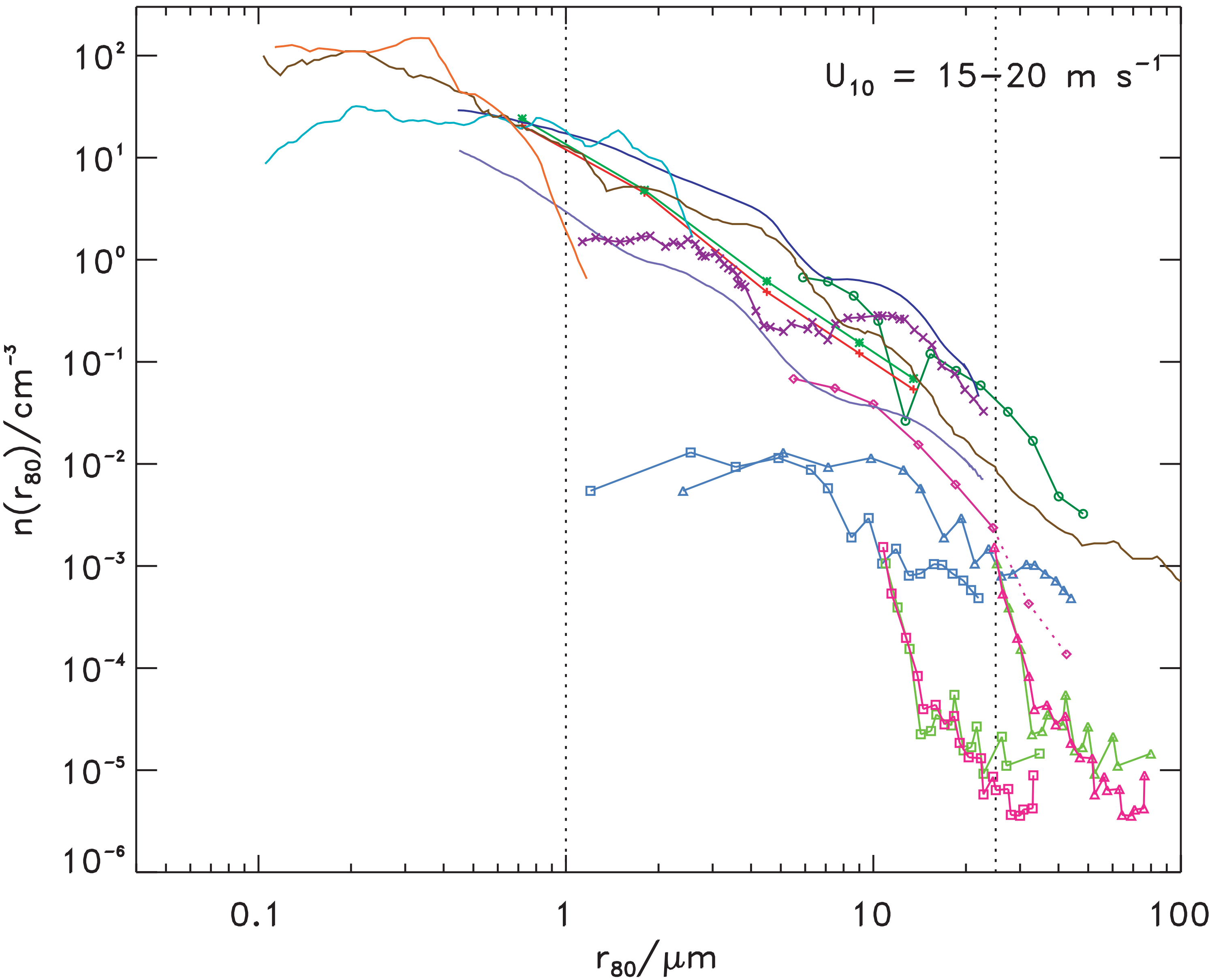
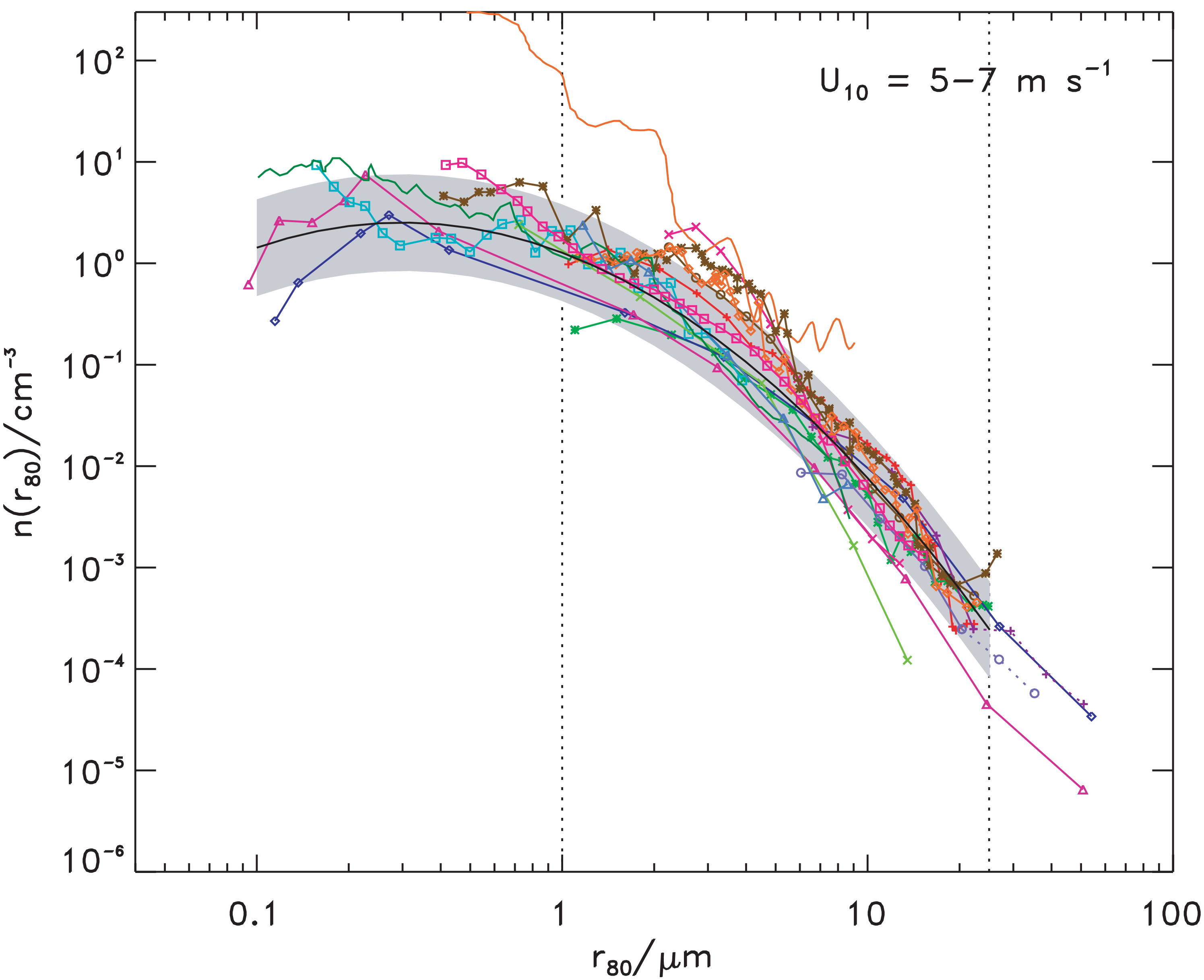


SIZE DISTRIBUTION OF SSA NUMBER CONCENTRATION

- *Shape* (size dependence of $n(r_{80})$) roughly independent of wind speed
- General *increase* in $n(r_{80})$ with increasing wind speed U_{10}
- Order of magnitude *variability* in $n(r_{80})$ at given U_{10}
- *Range of interest* 0.1 μm < r_{80} < 25 μm
  - Few SSA particles with r_{80} < 0.1 μm
  - SSA particles with r_{80} > 25 μm spend little time in the atmosphere
- Few data with r_{80} < 1 μm
- No evidence of multiple modes

SIZE DISTRIBUTION OF SSA NUMBER CONCENTRATION



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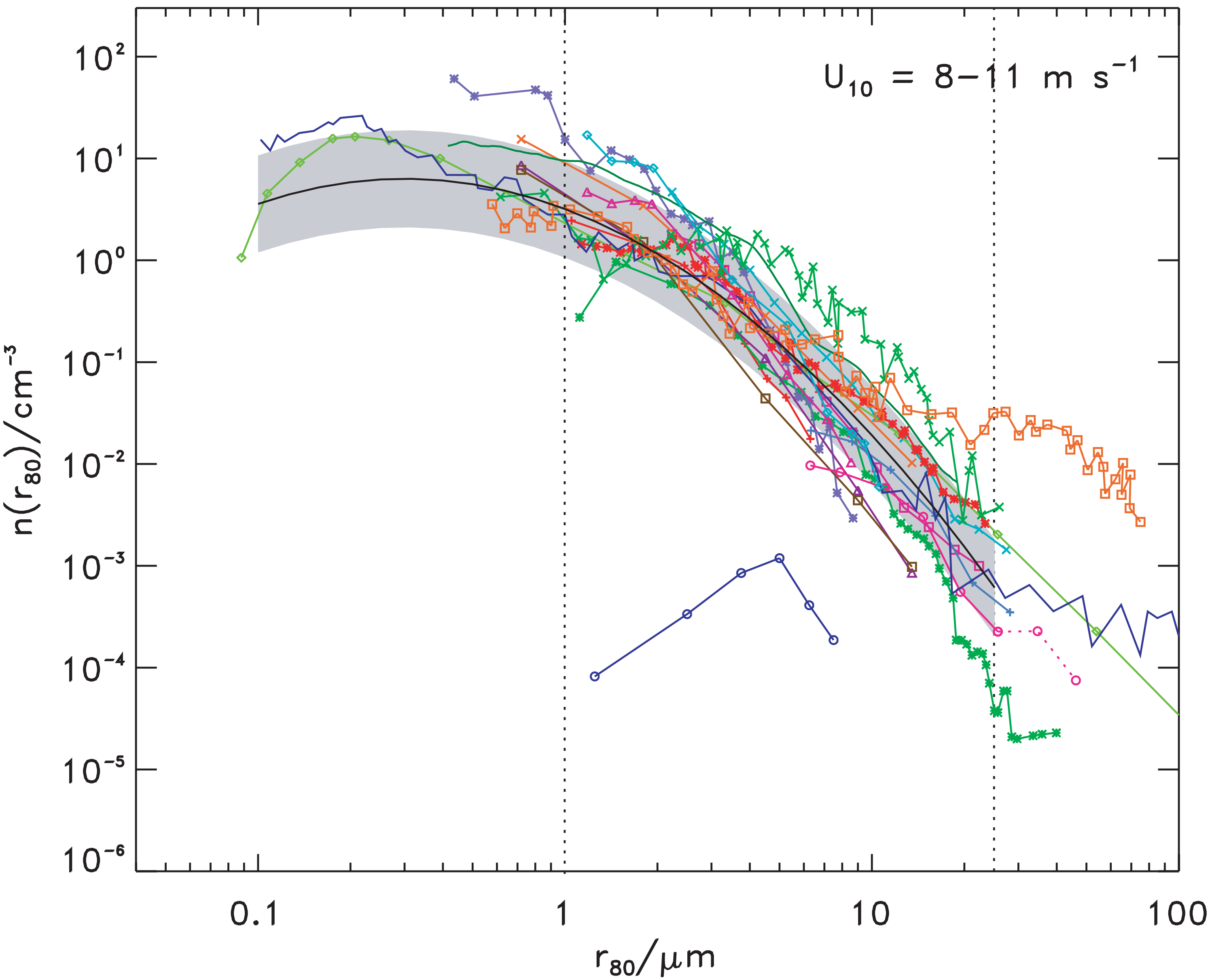

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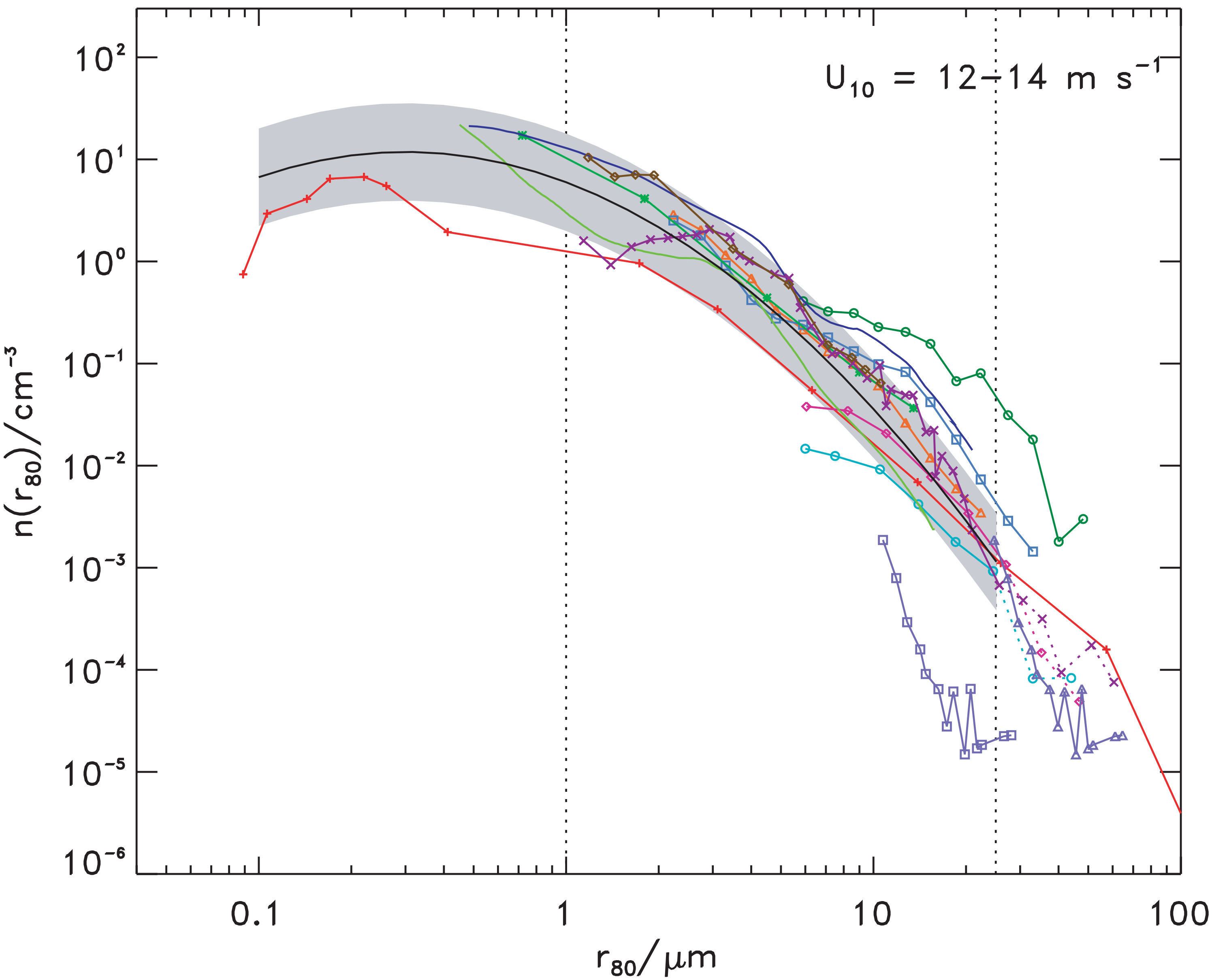

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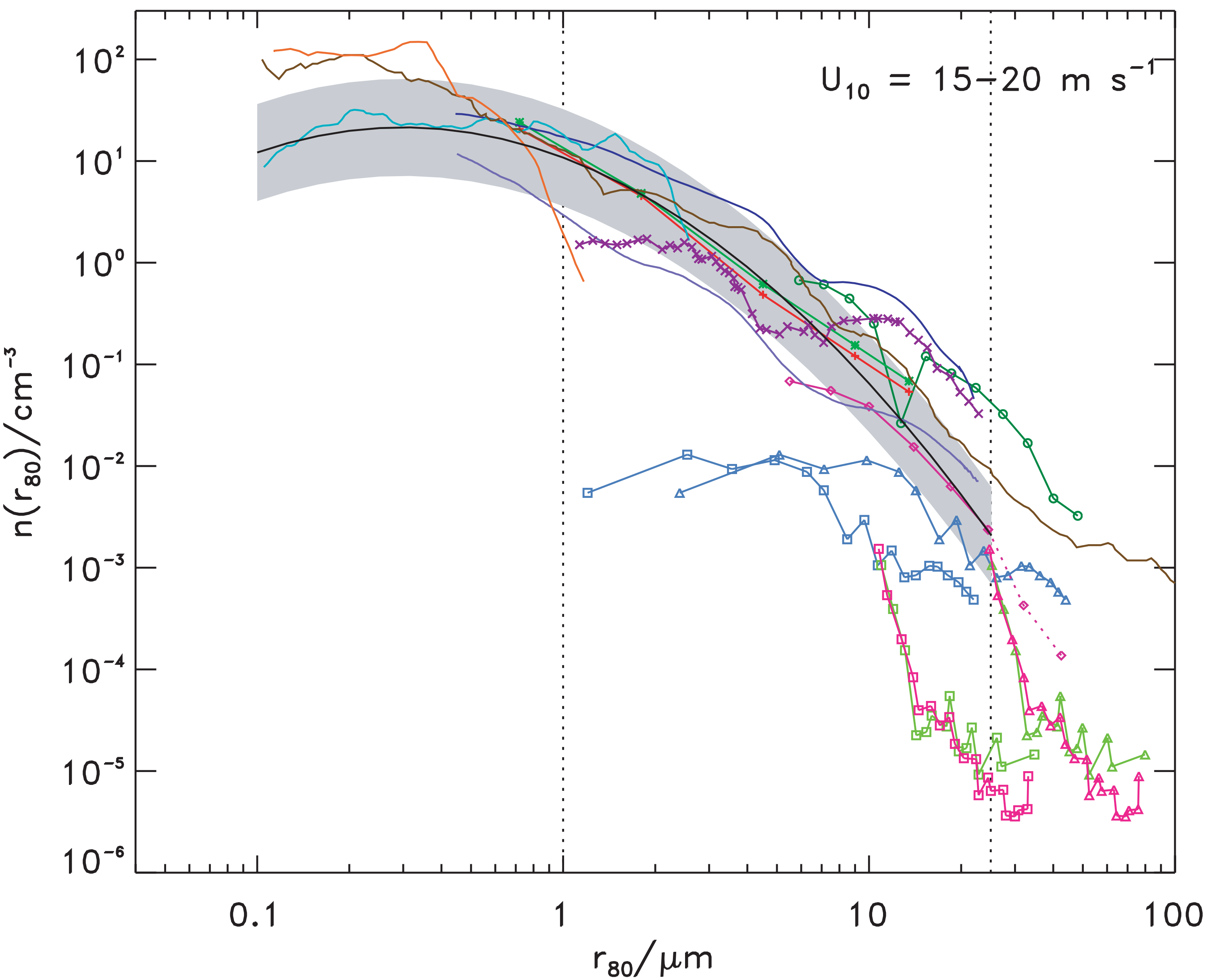


PARAMETERIZATION of SIZE DISTRIBUTION of SSA CONCENTRATION

$$\left(dN \middle/ d\log r_{80} \right) \Big/ \mathrm{cm}^{-3} = 0.07 \left(\frac{U_{10}}{\mathrm{m\ s}^{-1}} \right)^2 \exp\left\{ -\frac{1}{2} \left[\frac{\ln\left(r_{80} / 0.3\,\mu\mathrm{m} \right)}{\ln 2.8} \right]^2 \right\}$$

Associated uncertainty $\overset{\times}{\div}$ 3 (***essential***)

$0.1\ \mu\mathrm{m} < r_{80} < 25\ \mu\mathrm{m}$

$5\ \mathrm{m\ s}^{-1} < U_{10} < 20\ \mathrm{m\ s}^{-1}$

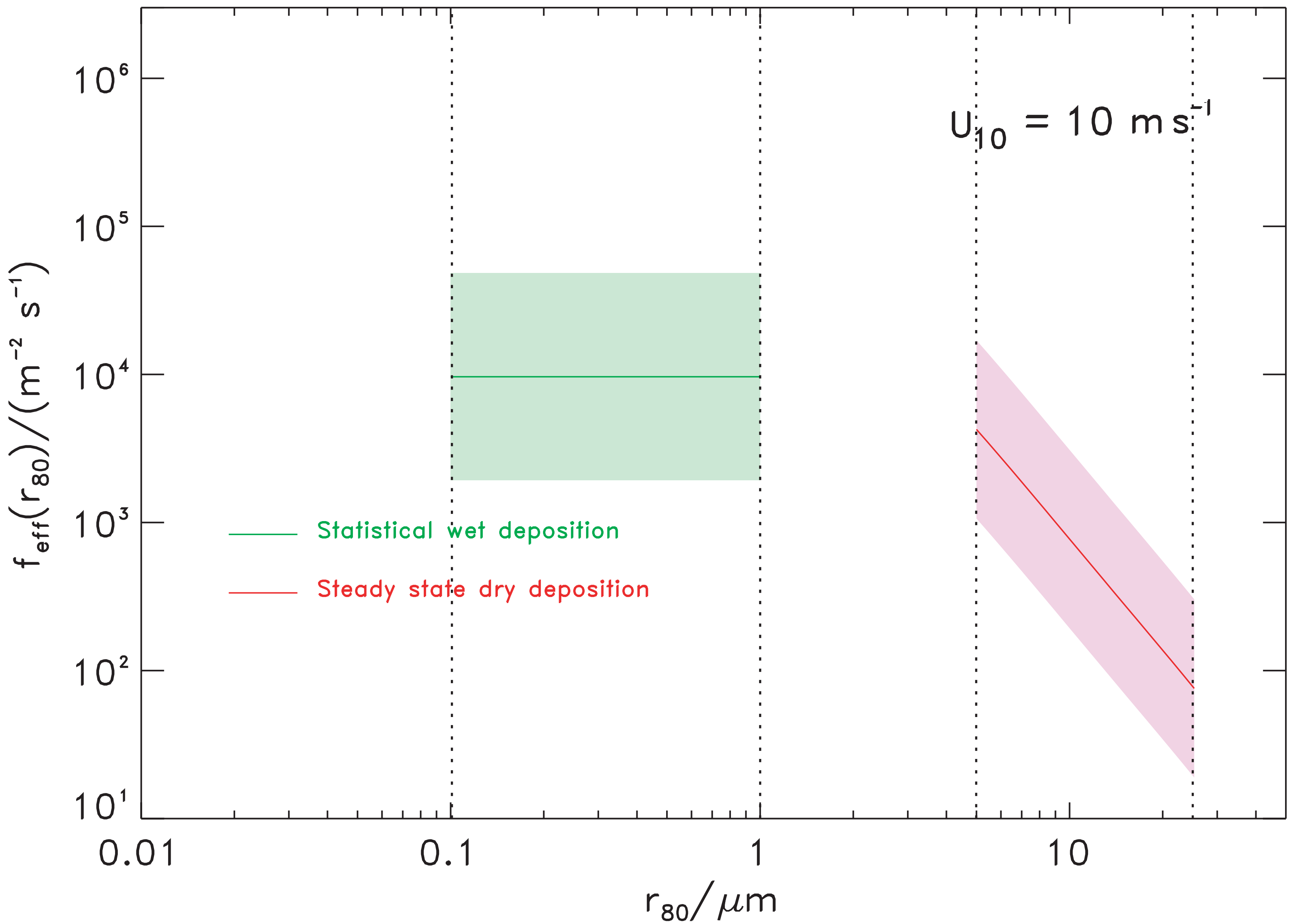
- Fits majority of data fairly well
- Lognormal - purely empirical
- Quadratic wind speed dependence; shape independent of wind speed
- Integral aerosol properties at $U_{10} = 10\ \mathrm{m\ s}^{-1}$:
  - $N = (8 \overset{\times}{\div} 3)\ \mathrm{cm}^{-3}$, mostly from $r_{80} = 0.1\text{-}1\ \mu\mathrm{m}$
  - $A = (80 \overset{\times}{\div} 3)\ \mu\mathrm{m}^2\ \mathrm{cm}^{-3}$, mostly from $r_{80} = 1\text{-}10\ \mu\mathrm{m}$

    $\Rightarrow \sigma_{\mathrm{sp}} \approx (40 \overset{\times}{\div} 3)\ \mathrm{Mm}^{-1},\ \tau_{\mathrm{sp}} \approx 0.02 \overset{\times}{\div} 3$
  - $M = (30 \overset{\times}{\div} 3)\ \mu\mathrm{g\ m}^{-3}$, mostly from $r_{80} = 3\text{-}20\ \mu\mathrm{m}$

PRINCIPAL METHODS of DETERMINING SSA PRODUCTION FLUX

Method	Equation	r_{80} range
Steady State Dry Deposition	$f_{\mathrm{eff}}(r_{80}) = n(r_{80})\cdot v_{\mathrm{d}}(r_{80})$	~3 - ~25 µm
Statistical Wet Deposition	$f_{\mathrm{eff}}(r_{80}) = n(r_{80})\cdot H_{\mathrm{mbl}}/\tau_{\mathrm{wet}}$	< ~1 µm
Concentration Buildup	$f_{\mathrm{eff}}(r_{80}) = U\dfrac{\partial}{\partial x}\left[\int n(r_{80}, x, z)\,dz\right]$	< ~10 µm
Micrometeorological (Eddy correlation)	$f_{\mathrm{eff}}(r_{80}) = \overline{n'(r_{80})w'}$	< ~1 µm
Whitecap	$f_{\mathrm{int}}(r_{80}) = f_{\mathrm{wc}}(r_{80})\cdot W(U_{10})$	< ~10 µm

EFFECTIVE SSA PRODUCTION FLUX



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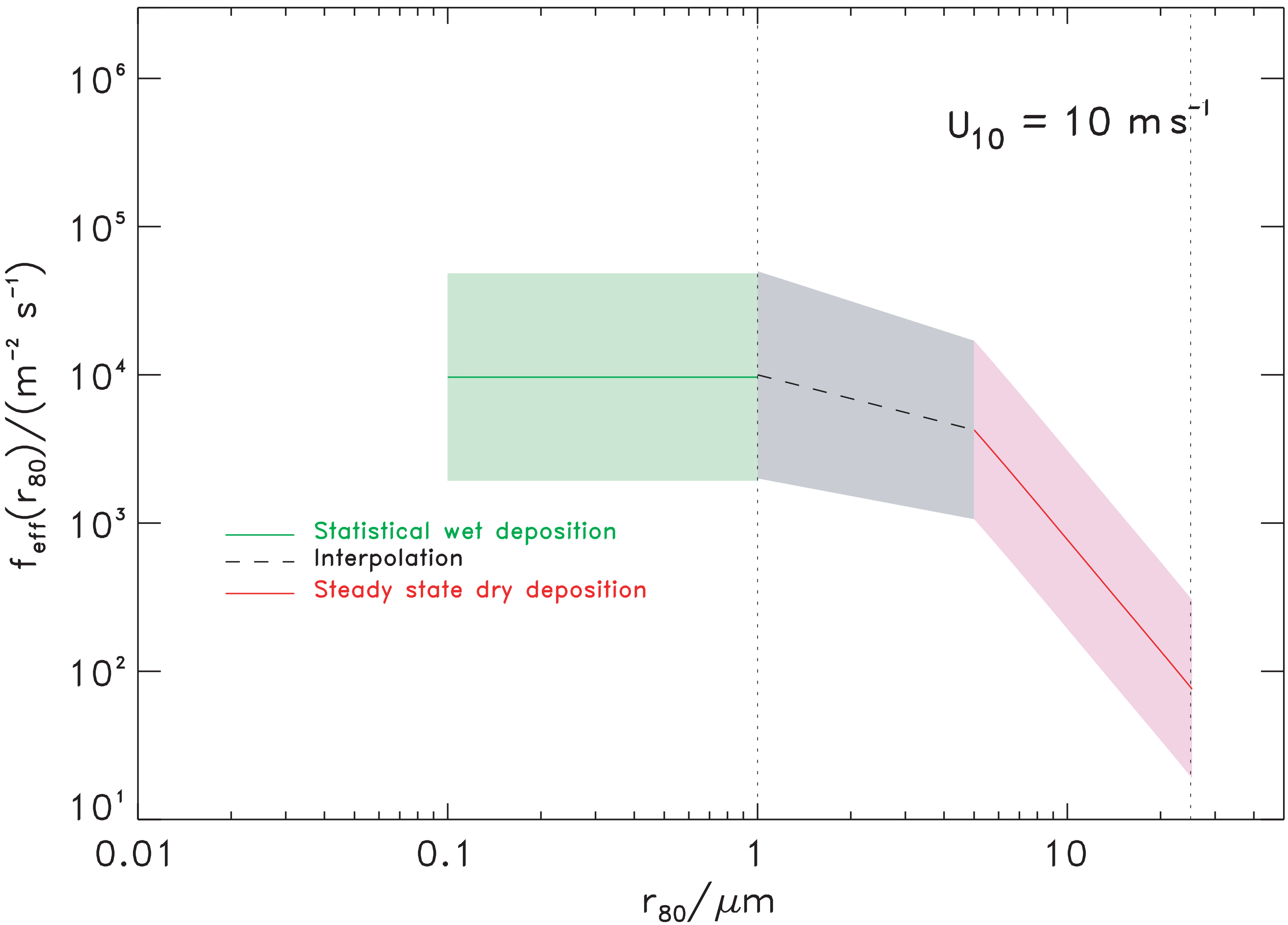

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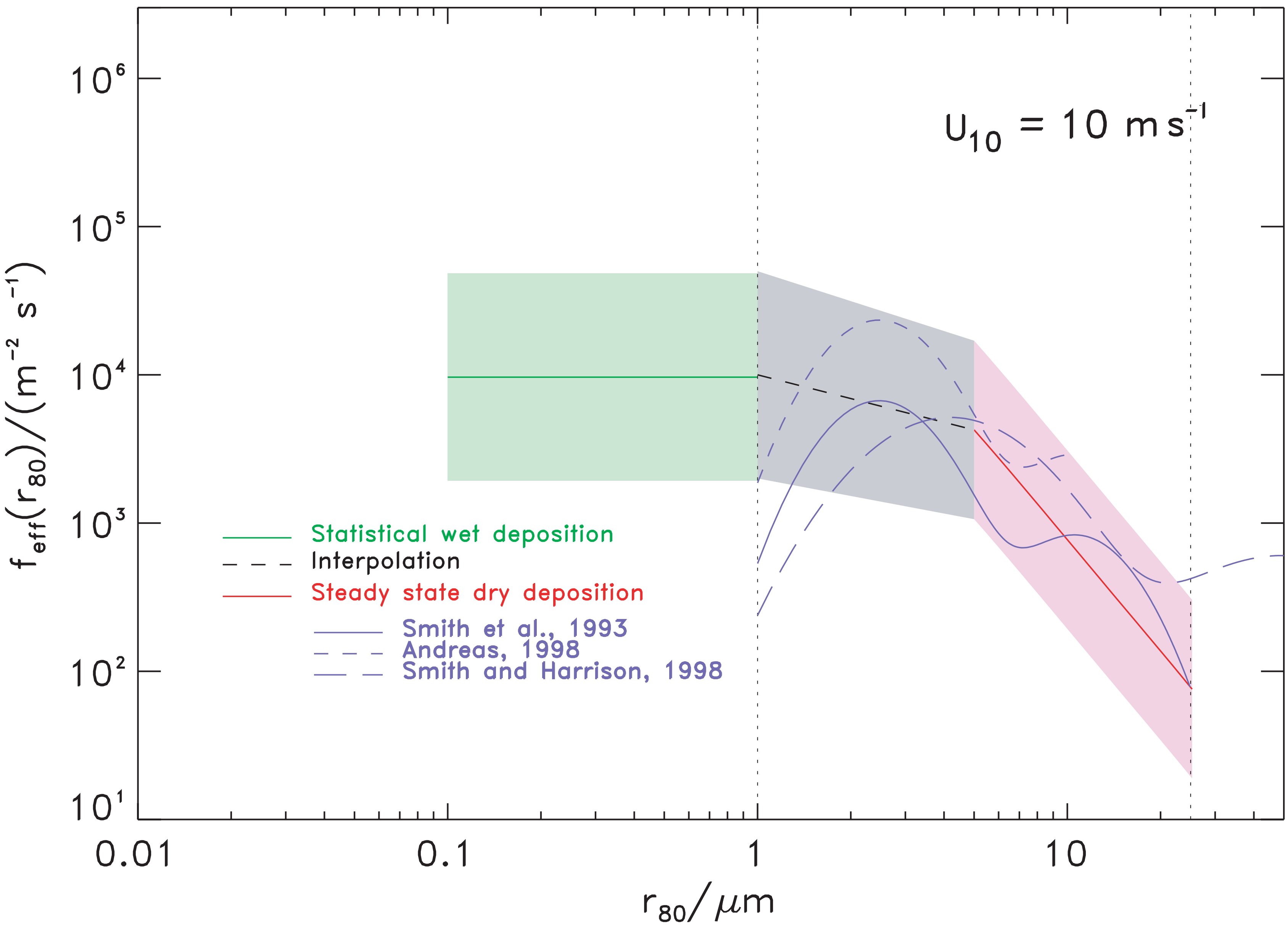

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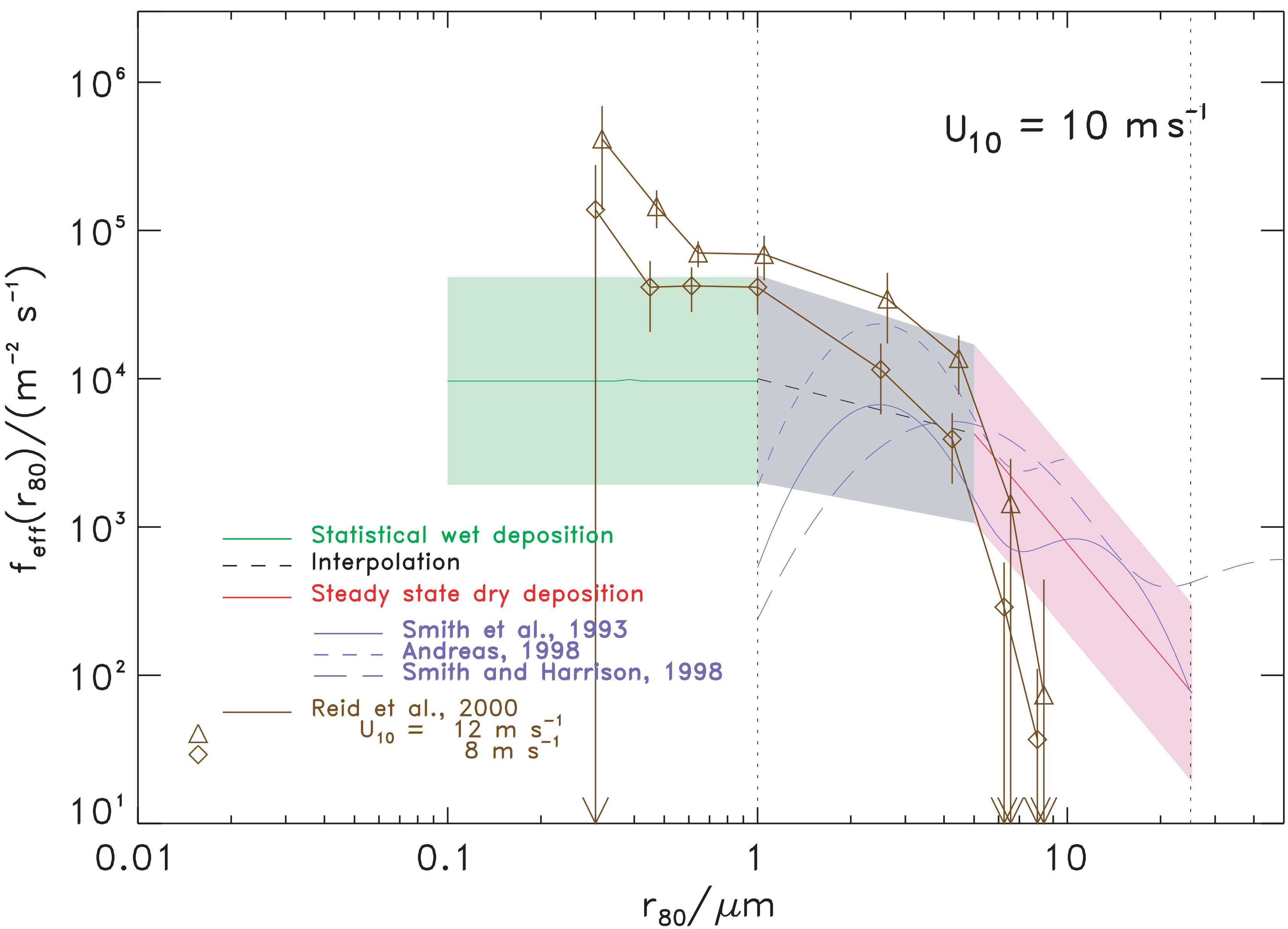

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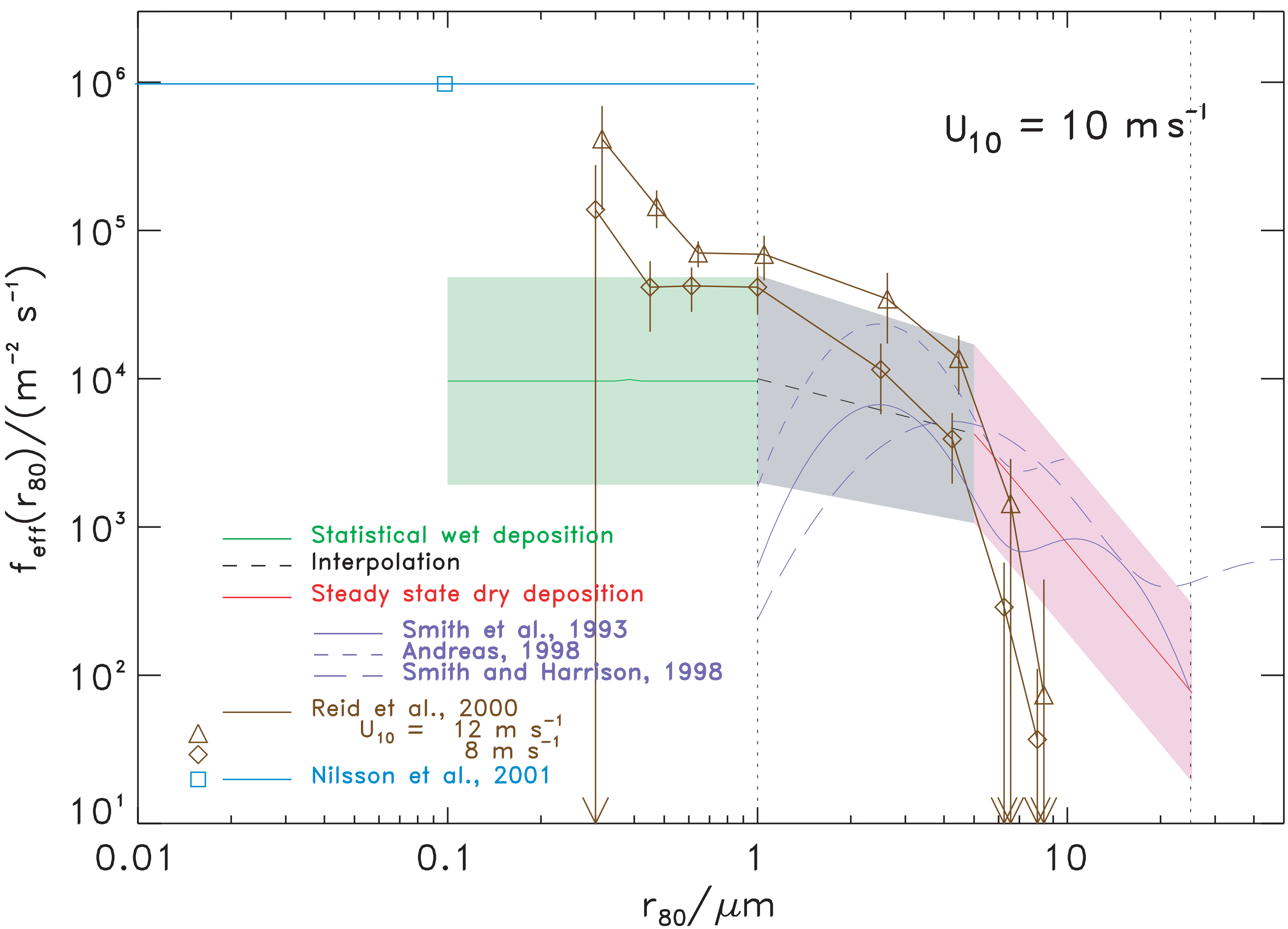

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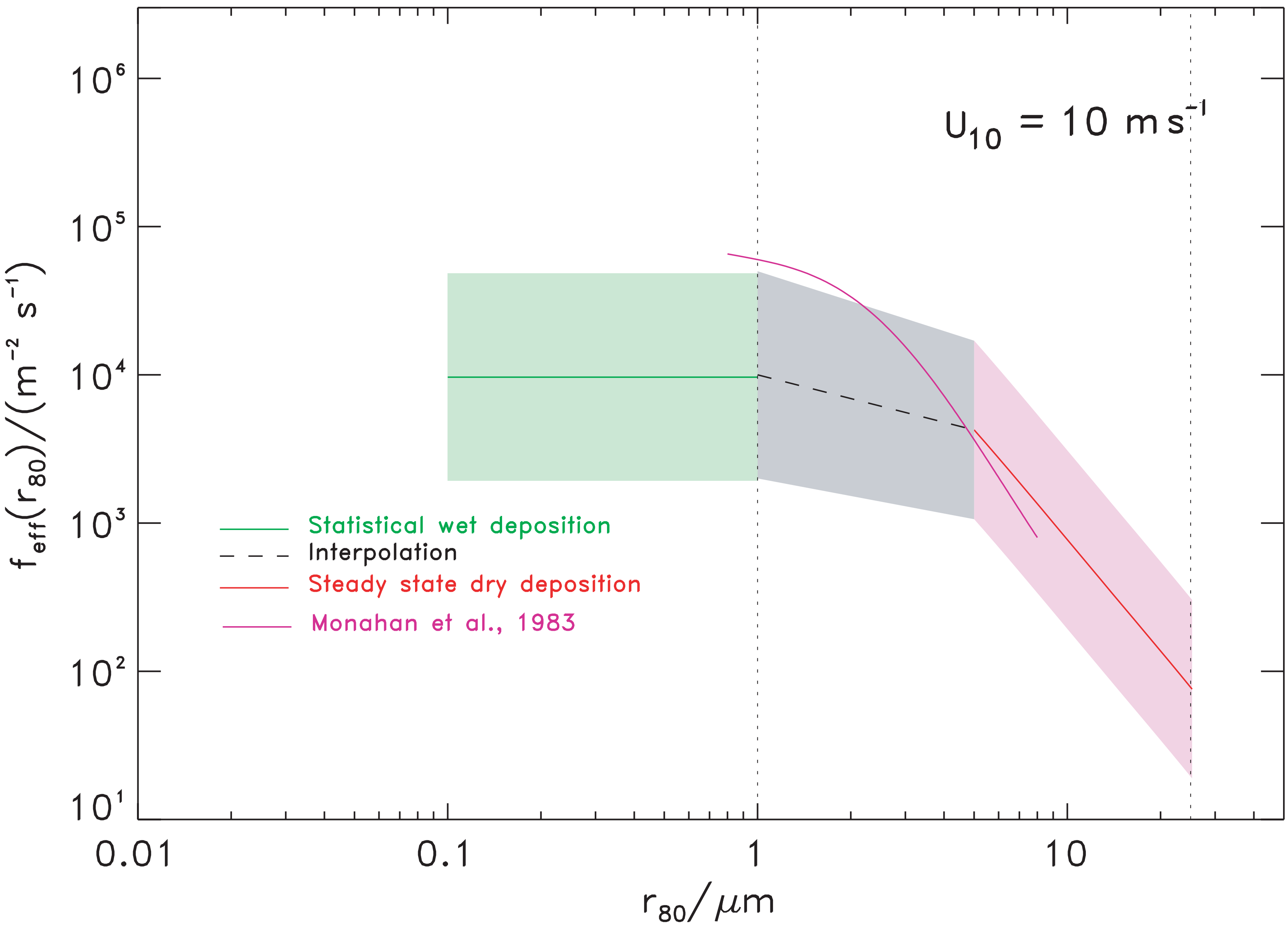

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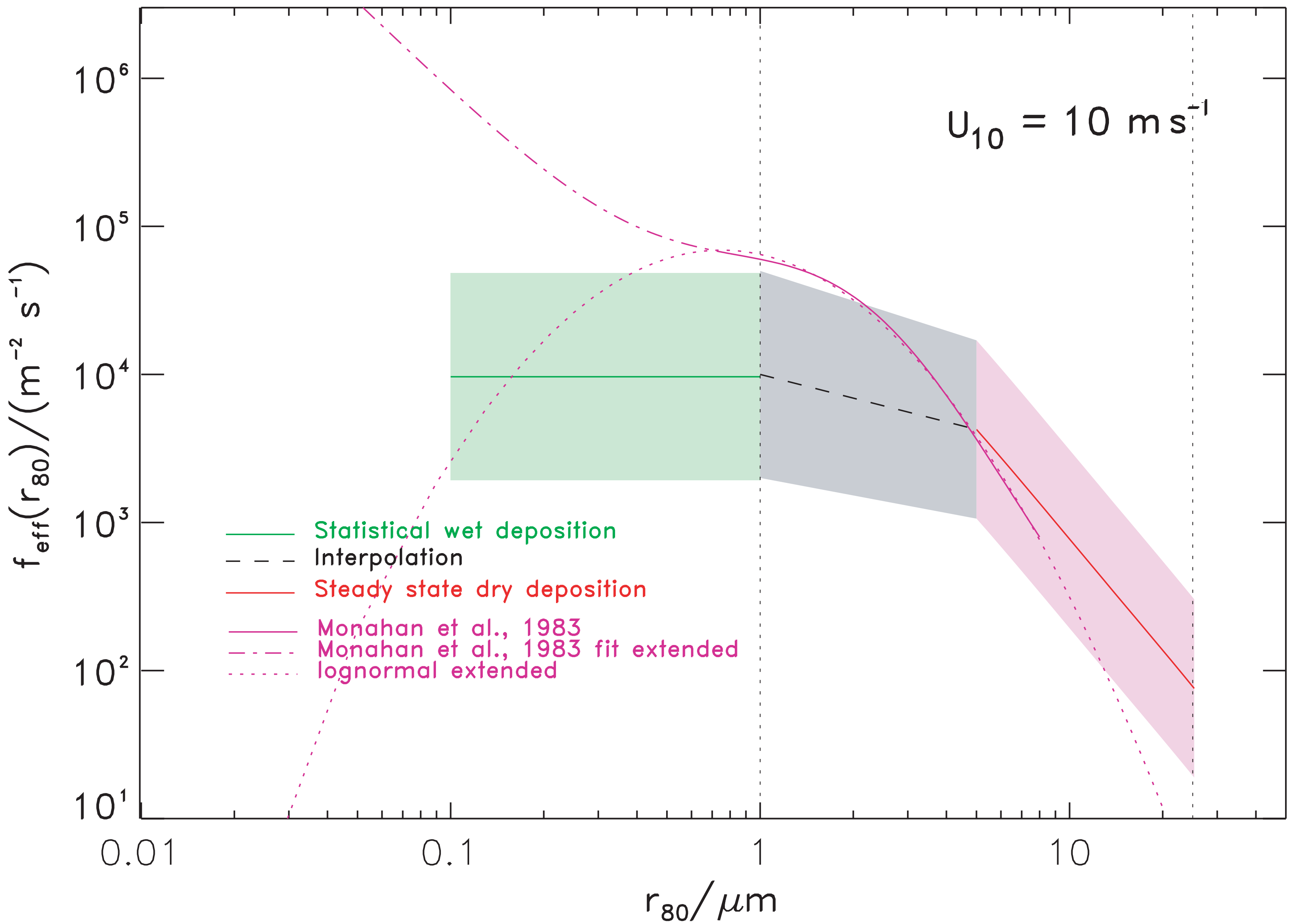

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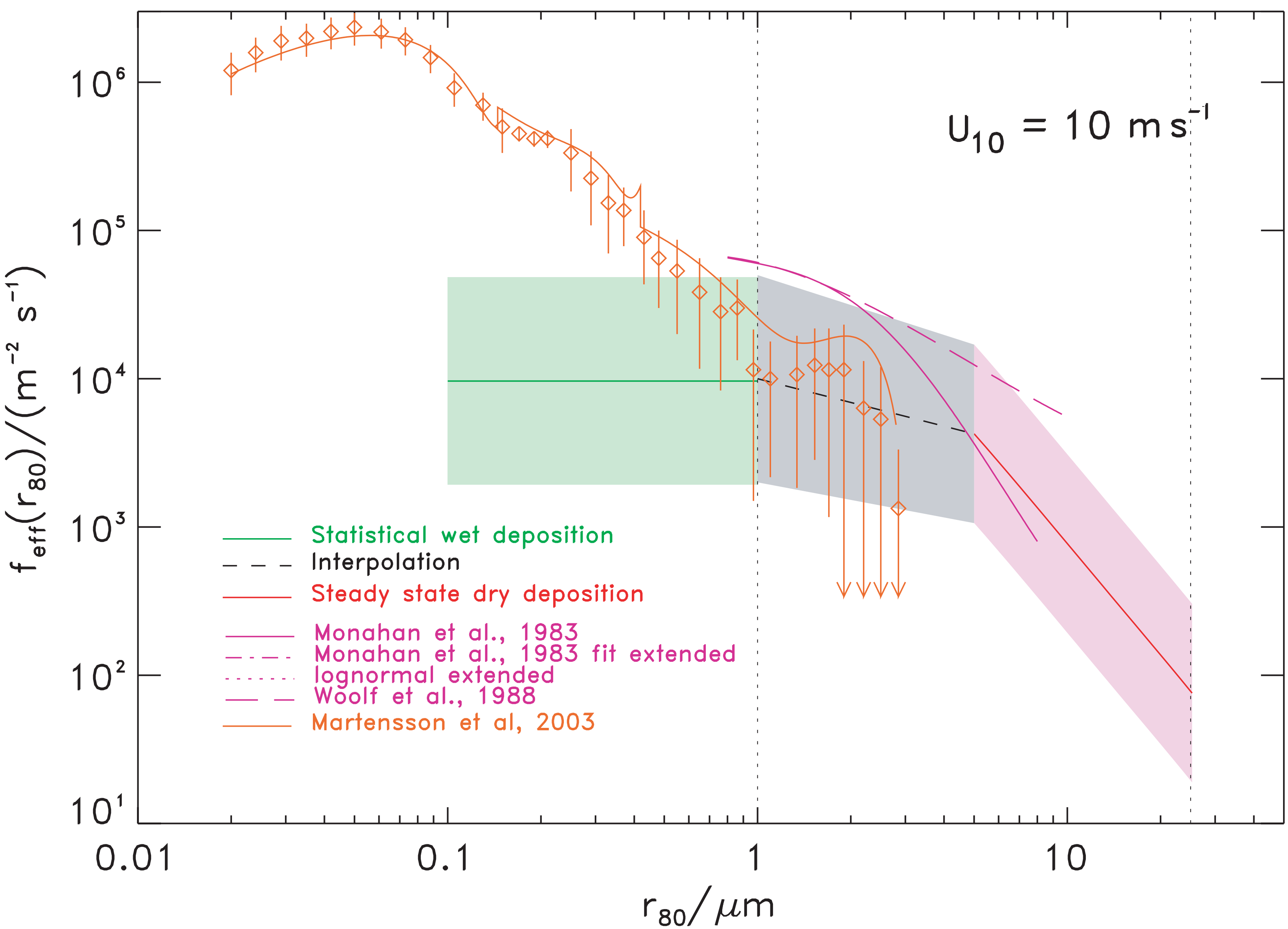

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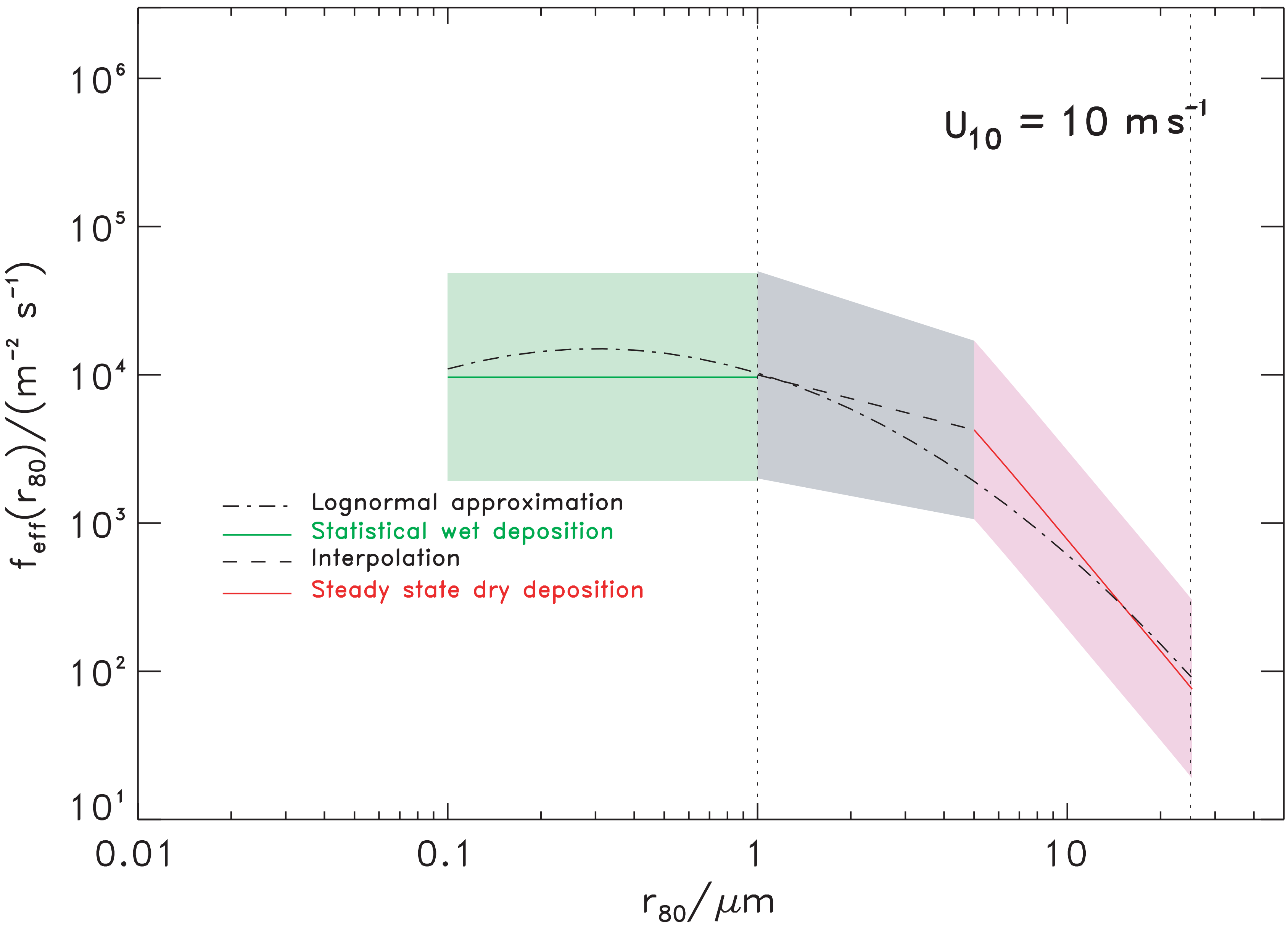


PARAMETERIZATION of SIZE DISTRIBUTION of EFFECTIVE SSA PRODUCTION FLUX

$$\left(dF_{\text{eff}} \big/ d\log r_{80} \right) \Big/ \left(\text{m}^{-2}\,\text{s}^{-1} \right) = 50 \left(\frac{U_{10}}{\text{m s}^{-1}} \right)^{2.5} \exp\left\{ -\frac{1}{2} \left[\frac{\ln\left(r_{80} / 0.3\,\mu\text{m} \right)}{\ln 4} \right]^2 \right\}$$

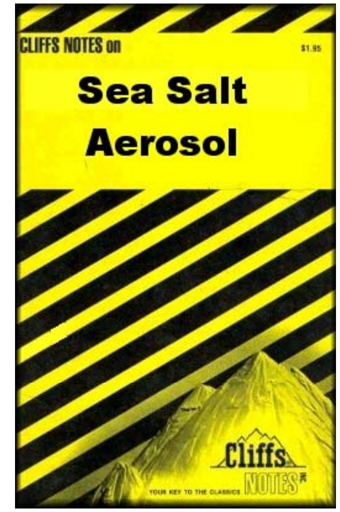
Associated uncertainty $\overset{\times}{\div}$ 5 (***essential***)

$0.1\ \mu\text{m} < r_{80} < 25\ \mu\text{m}$

$5\ \text{m s}^{-1} < U_{10} < 20\ \text{m s}^{-1}$

- Purely empirical
- Lognormal shape (i.e., size dependence) independent of wind speed

SUMMARY



Size $r_{80} \approx 2r_{\mathrm{dry}} \approx (1/2)r_{\mathrm{form}}$

- Range of interest $r_{80} \approx 0.1\text{-}25$ μm

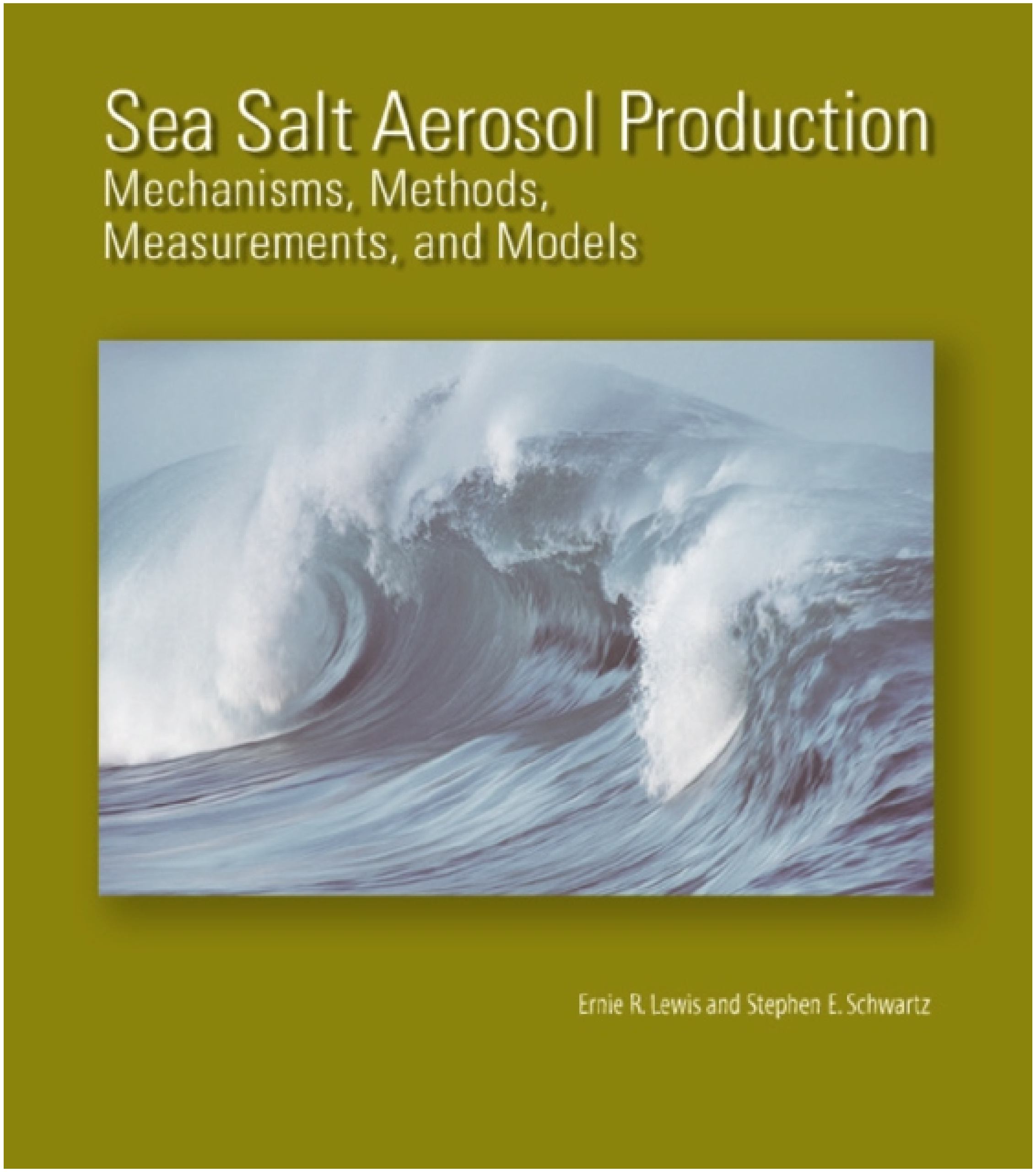
SSA concentration $n(r_{80})$ – uncertainty for given U_{10} is $\overset{\times}{\div}\,3$

- Concentrations increase roughly as ${U_{10}}^2$
- Shape of size distribution roughly independent of wind speed
  - **Number** concentration mostly $r_{80} \approx 0.1\text{-}1$ μm (CCN)
  - **Area** concentration mostly $r_{80} \approx 1\text{-}10$ μm (light scattering)
  - **Mass** concentration mostly $r_{80} \approx 3\text{-}20$ μm

Effective SSA production flux $f_{\mathrm{eff}}(r_{80})$ – uncertainty for given U_{10} is $\overset{\times}{\div}\,5$

- Flux increases roughly as ${U_{10}}^{2.5}$
- Shape of size distribution roughly independent of wind speed

http://www.ecd.bnl.gov/steve/SSA-AGUfm04.pdf



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